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(54) **ELECTRICAL CONNECTION SYSTEM FOR SHIELDED WIRE CABLE**

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H01R 9/03 (2006.01)
H01B 1/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .... ***H01R 9/03*** (2013.01); ***H01B 1/026*** (2013.01); ***H01B 7/1875*** (2013.01); (Continued)

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(Continued)

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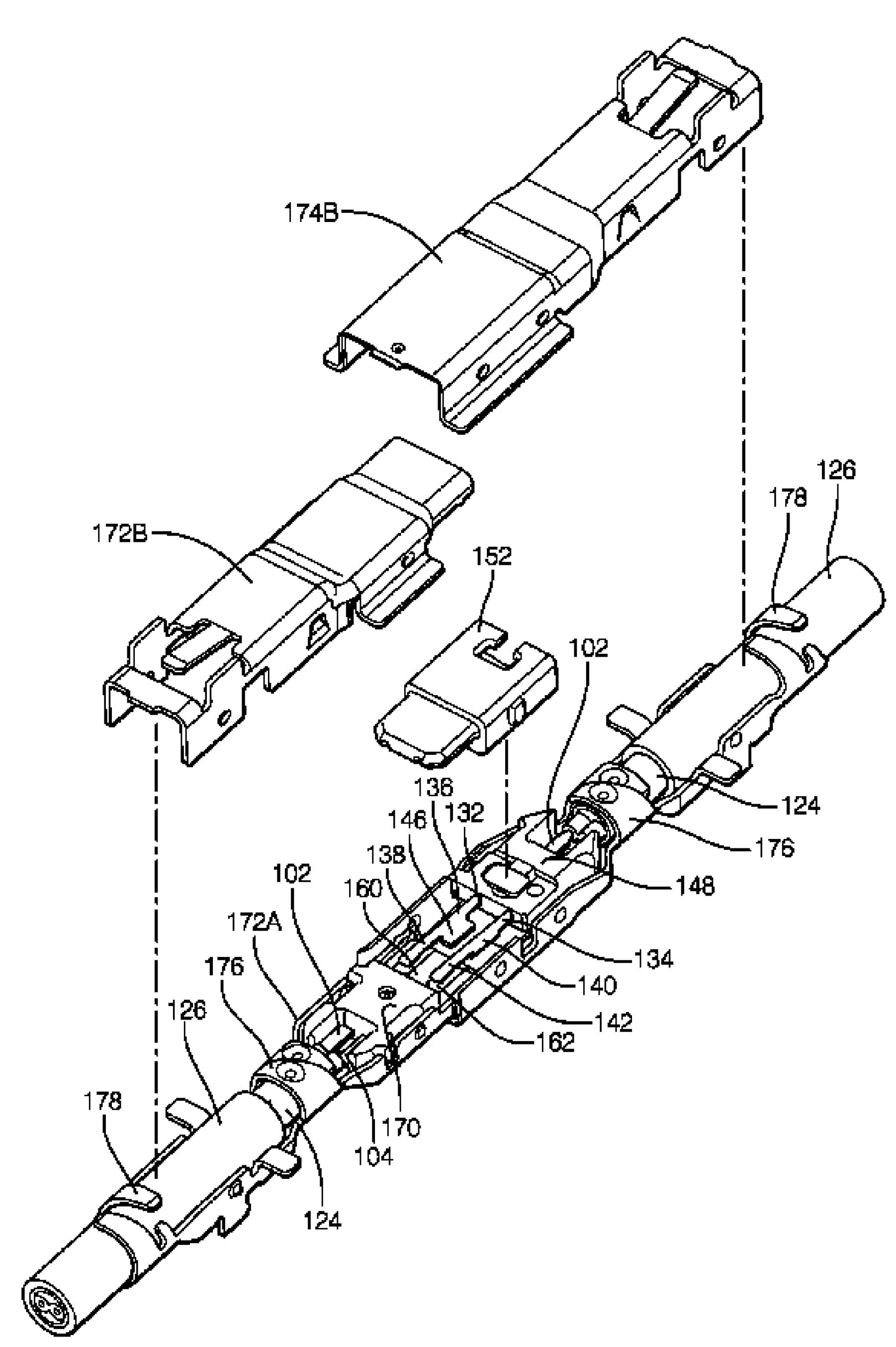
(57) **ABSTRACT**

An electrical connection system configured to terminate electrical connectors and to transmit digital electrical signals having a data transfer rate of 5 Gigabits per second (Gb/s) or higher. The system includes a first parallel mirrored pair of terminals having a planar connection portion and a second pair of parallel mirrored terminals having a cantilever beam portion and a contact points configured to contact the first terminals. The cantilever beam portions are generally perpendicular to the planar connection portions. The terminals cooperate to provide consistent characteristic impedance. The connection system further includes an electromagnetic shield that longitudinally surrounds the terminals. The connection system is suited for terminating wire cables transmitting digital signals using data transfer protocols such as Universal Serial Bus (USB) 3.0 and High Definition Multimedia Interface (HDMI) 1.4.

5 Claims, 10 Drawing Sheets



Related U.S. Application Data

application No. 14/101,472, filed on Dec. 10, 2013, now abandoned.

(51) **Int. Cl.**

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H01B 11/00	(2006.01)
H01R 13/6593	(2011.01)
H01B 11/10	(2006.01)
H01R 9/05	(2006.01)
H01R 13/6582	(2011.01)

(52) **U.S. Cl.**

CPC ***H01B 11/002*** (2013.01); ***H01R 9/032*** (2013.01); ***H01R 13/6593*** (2013.01); *H01B 11/1091* (2013.01); *H01R 9/0518* (2013.01); *H01R 13/6582* (2013.01)

(58) **Field of Classification Search**

CPC H01R 9/03; H01R 9/032; H01R 9/0518; H01R 9/0512; H01B 7/1875; H01B 11/002; H01B 11/1091

See application file for complete search history.

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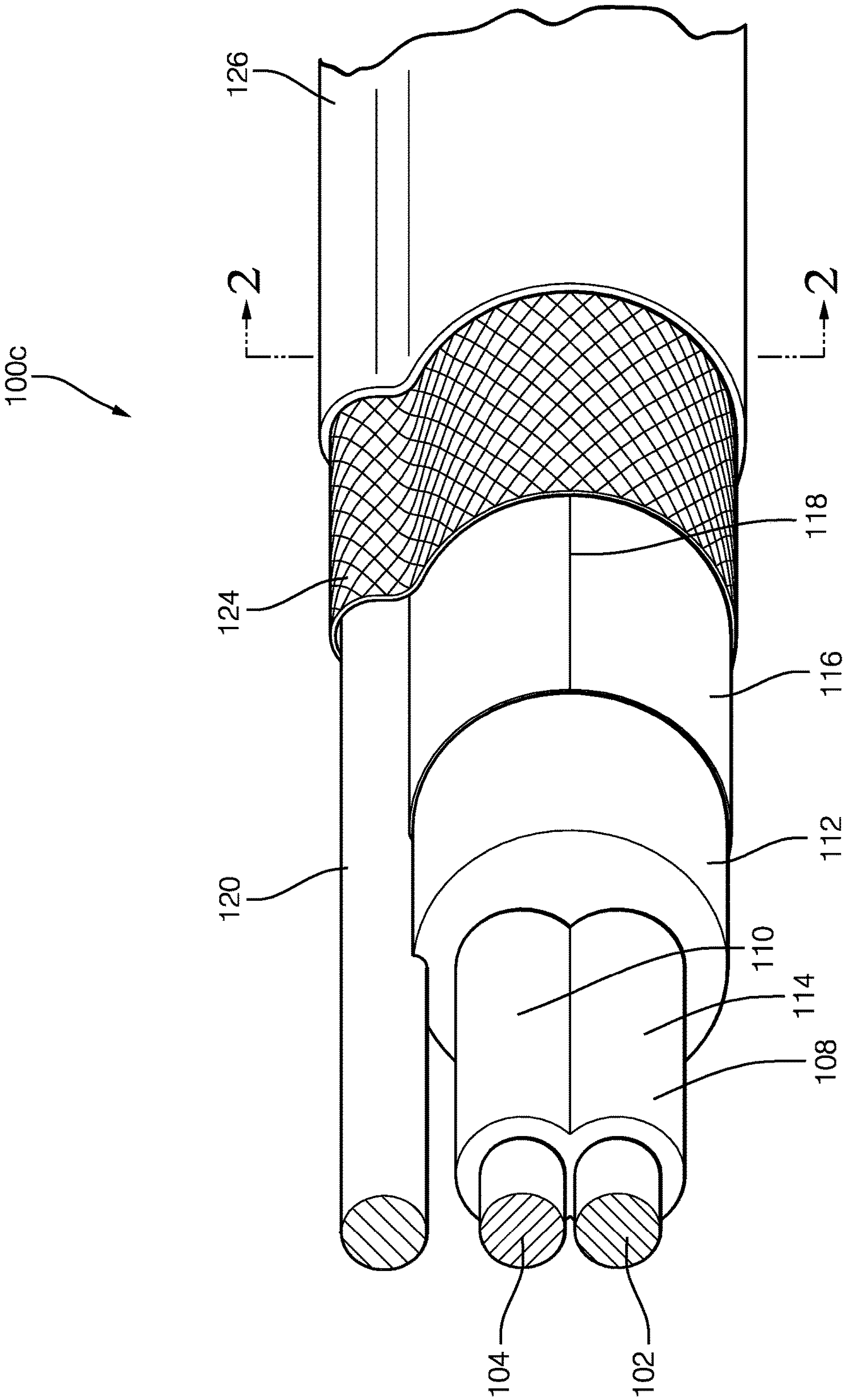

FIG. 1

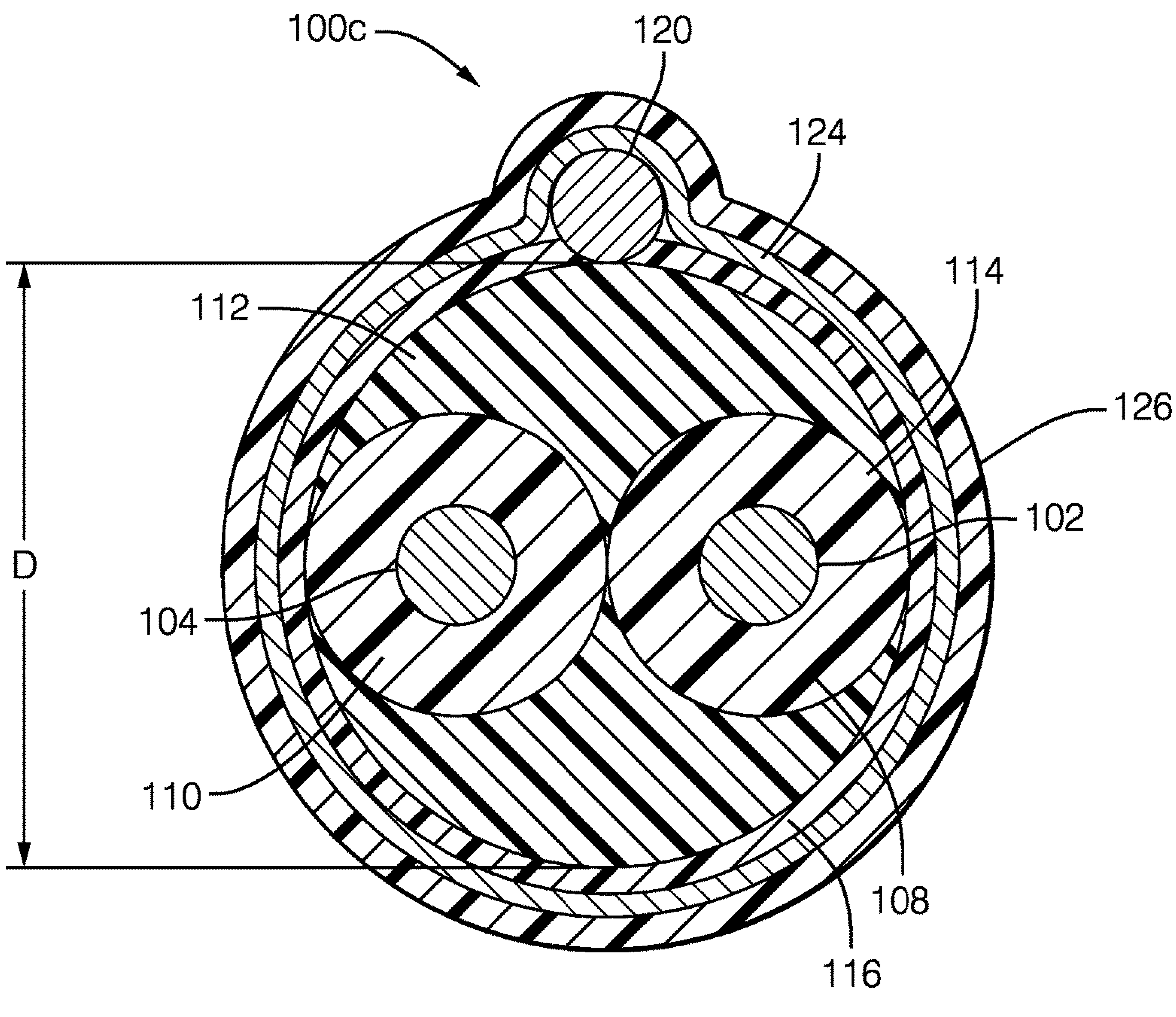

FIG. 2

STANDARD	RISE TIME	NOMINAL IMPEDANCE	MINIMUM IMPEDANCE	MAXIMUM IMPEDANCE
HDMI 1.4	200 ps	100 Ω	85 Ω	115 Ω
USB 3.0	50 ps	90 Ω	76.5 Ω	105 Ω
COMBINED	50 ps	95 Ω	85 Ω	105 Ω

FIG. 3

DIELECTRIC STRENGTH	0.5 KILOVOLTS/MINUTE	
MAXIMUM DC RESISTANCE AT 20° C	350Ω/km	
IMPEDANCE (TDR)	95 Ω	
INTERPAIR SKEW	< 15 ps/METER	
ATTENUATION/7 METERS	≤ 1.5 DECIBELS(dB)	@ < 100 MEGAHERTZ (MHz)
	≤ 5 dB	@ < 100 MHz - 1250 MHz
	≤ 7.5 dB	@ < 1250 MHz - 2500 MHz
	≤ 25 dB	@ < 2500 MHz - 7500 MHz
BENDING RADIUS	≤ 31 mm	

FIG. 4

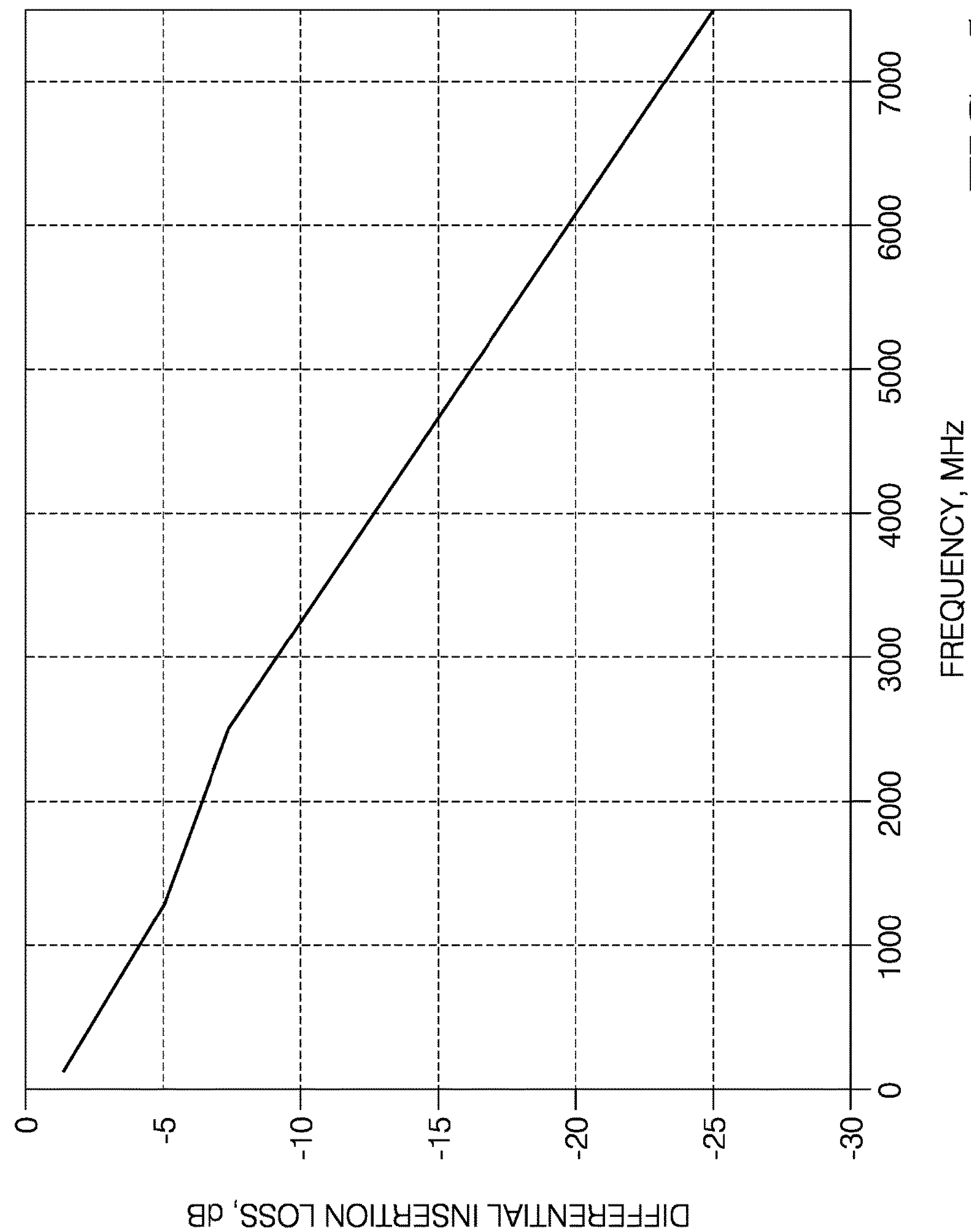
DIFFERENTIAL INSERTION LOSS, dB
0
-5
-10
-15
-20
-25
-30
FREQUENCY, MHz
0
1000
2000
3000
4000
5000
6000
7000

FIG. 5

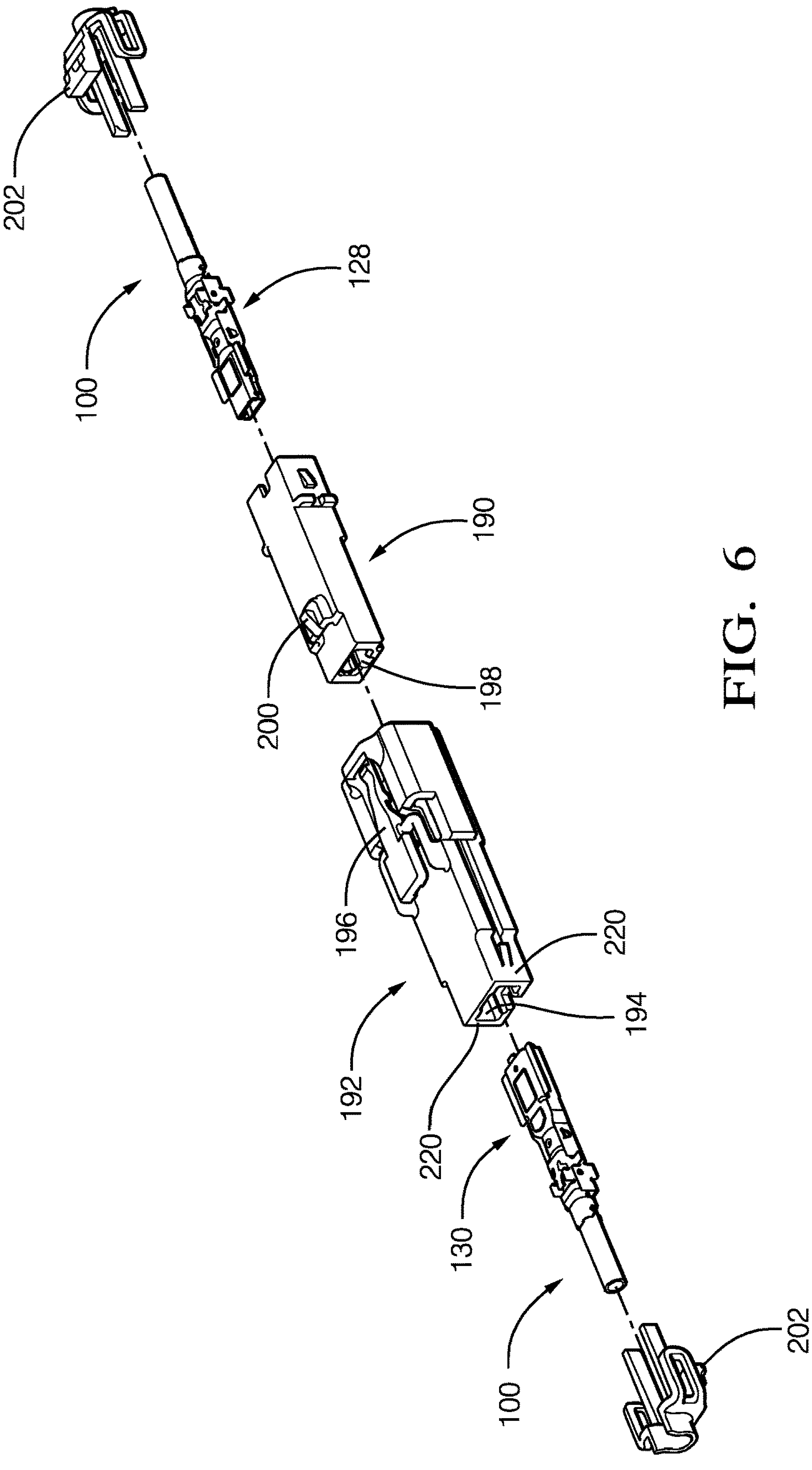

FIG. 6

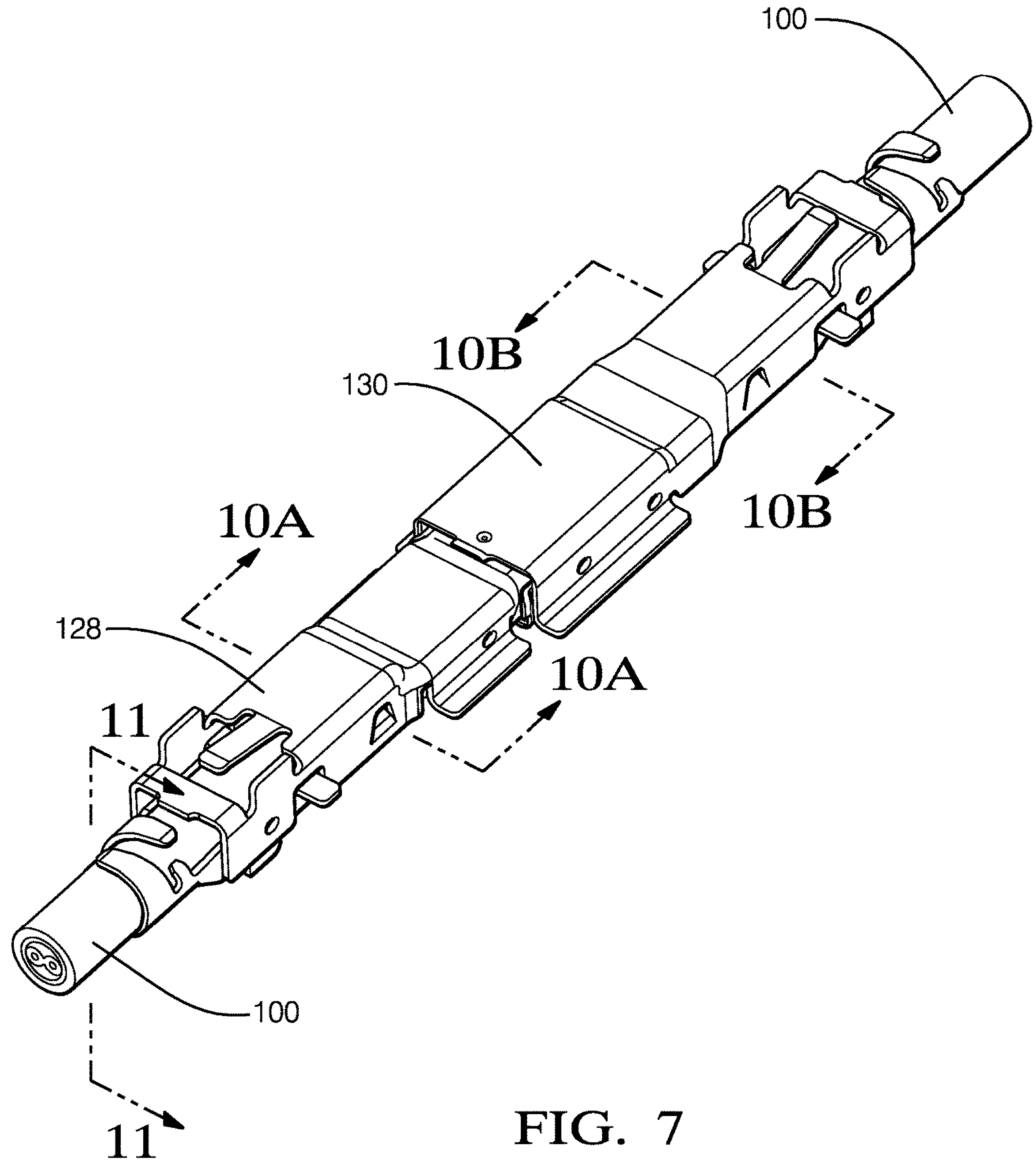

FIG. 7

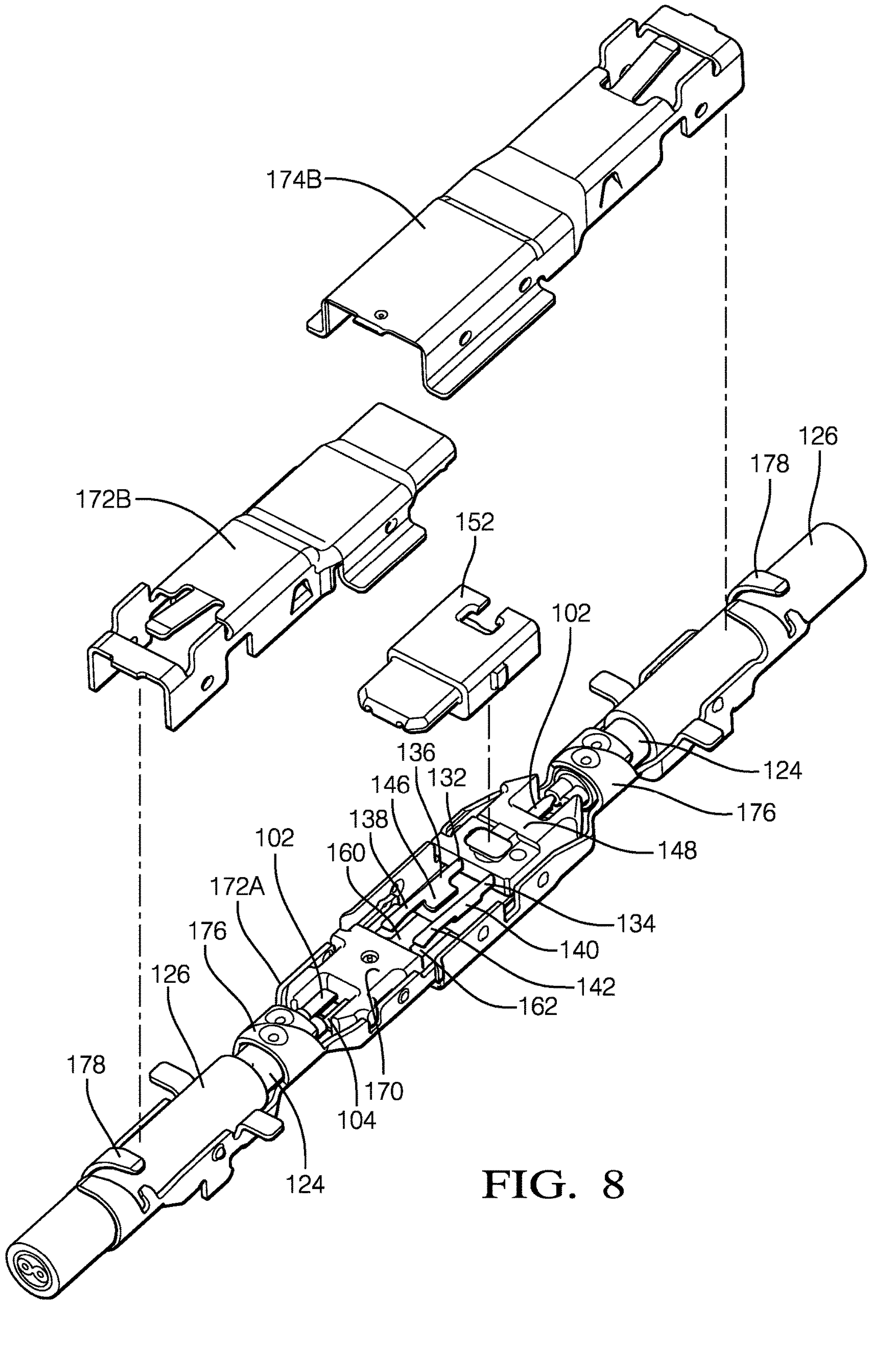
174B
172B
152
126
178
102
136
146
132
138
102
160
172A
176
126
178
124
176
148
134
140
142
162
170
104
124

FIG. 8

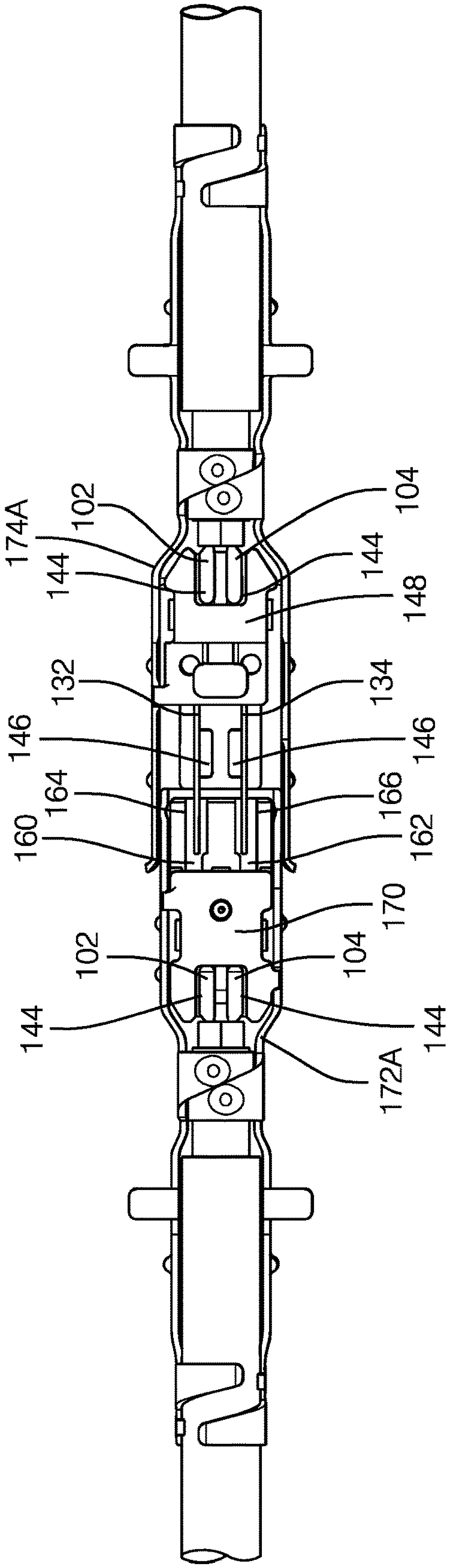
174A
102
104
144
144
148
132
134
146
146
164
166
160
162
170
102
104
144
144
172A

FIG. 9

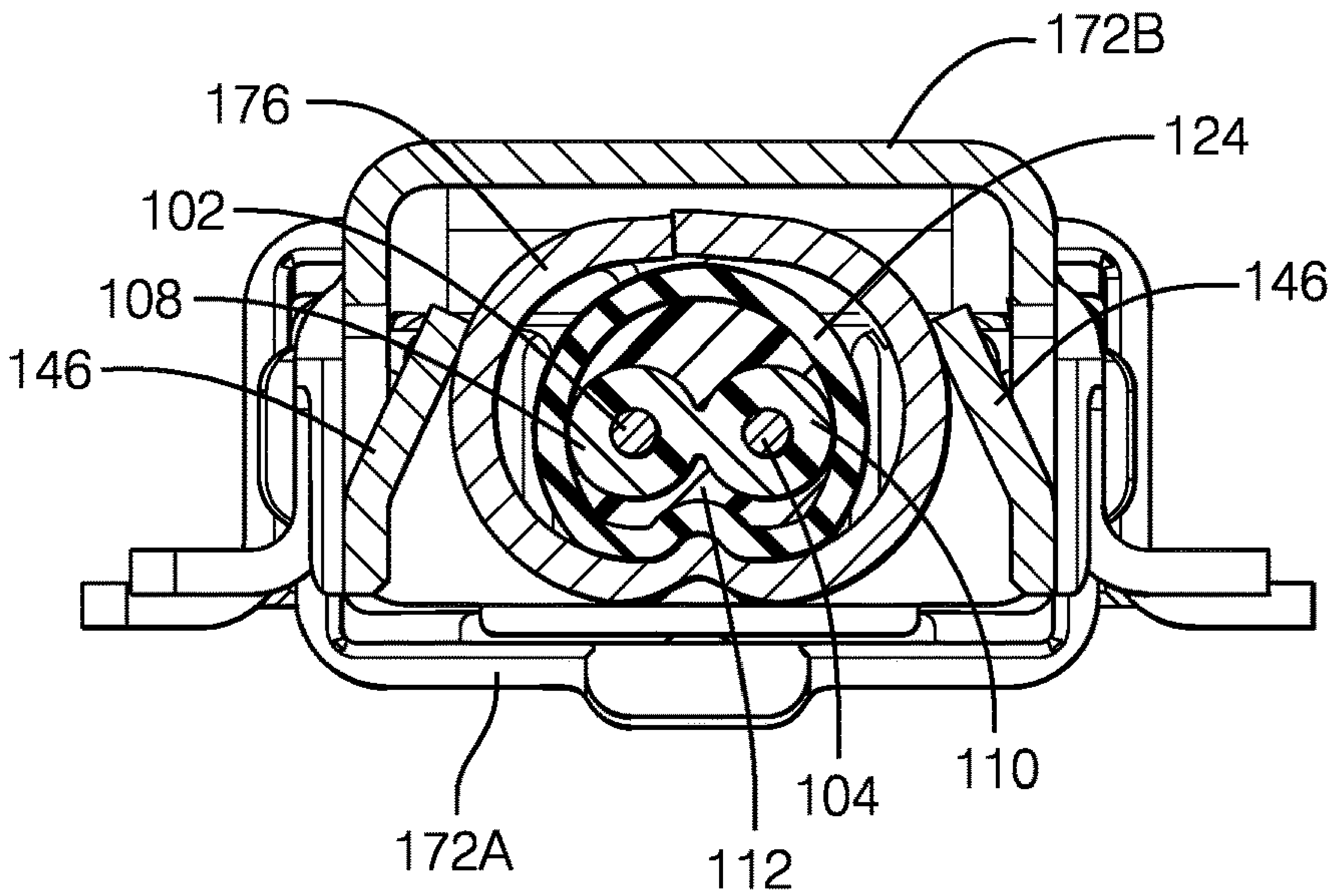

FIG. 10A

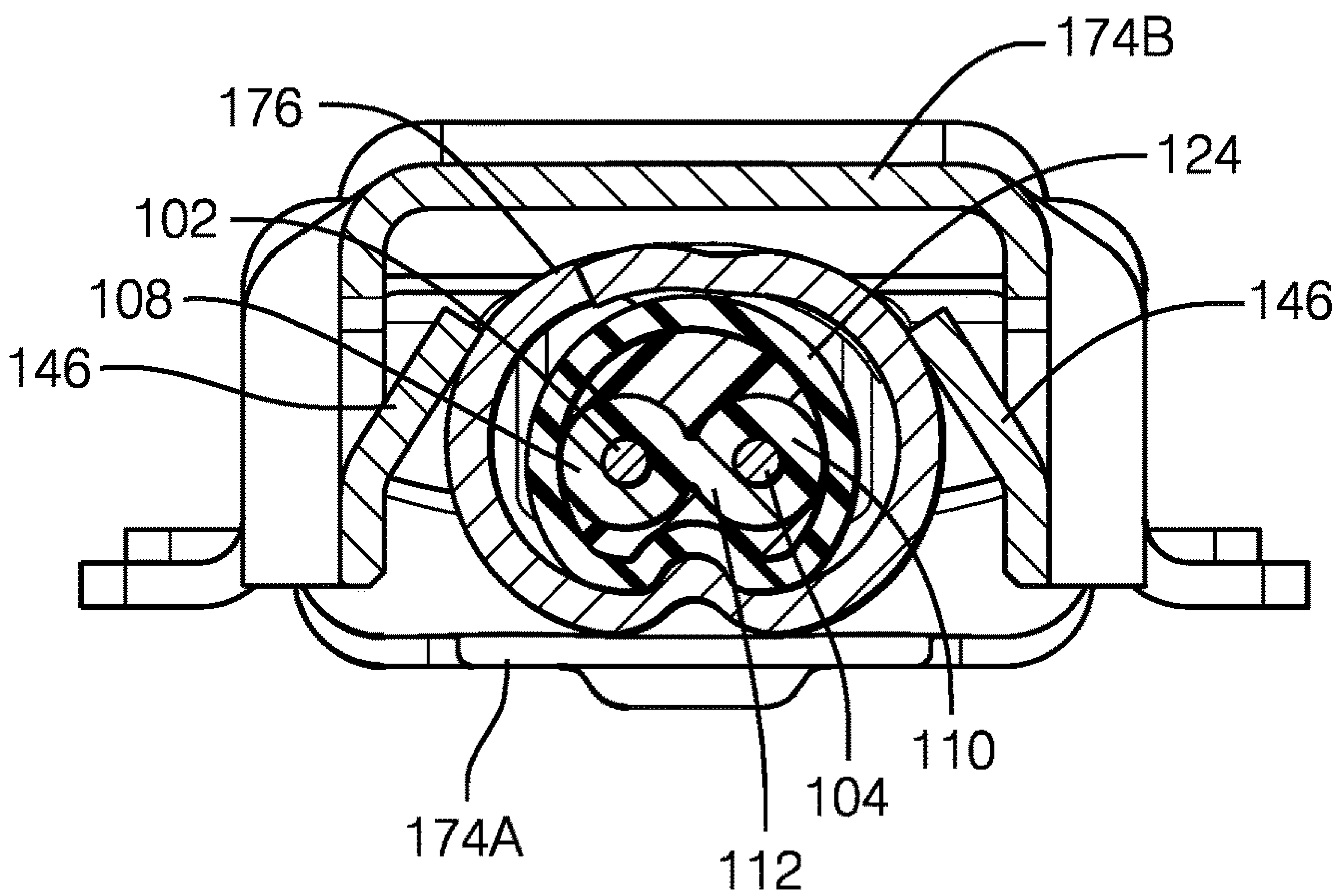

FIG. 10B

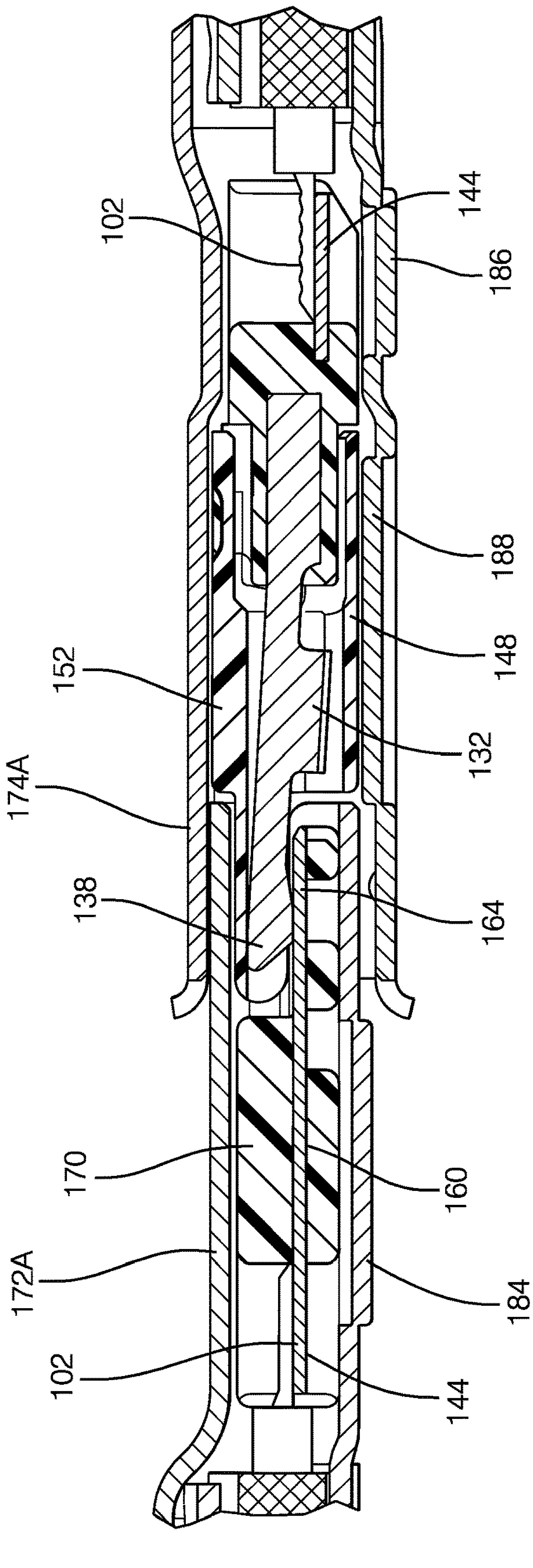
102
144
186
188
148
152
132
174A
138
164
170
160
172A
184
102
144

FIG. 11

ELECTRICAL CONNECTION SYSTEM FOR SHIELDED WIRE CABLE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part application and claims the benefit under 35 U.S.C. § 120 of U.S. patent application Ser. No. 15/369,973, filed Dec. 6, 2016 which claims the benefit under 35 U.S.C. § 120 of U.S. patent application Ser. No. 14/101,472, filed Dec. 12, 2013, the entire disclosure of both of which is hereby incorporated herein by reference.

TECHNICAL FIELD OF INVENTION

The invention generally relates to an electrical connection system, and more particularly relates to an electrical connection system designed to connect shielded wire cables capable of differentially transmitting digital electrical signals having a data transfer rate of 5 Gigabits per second (Gb/s) or higher further requiring frequency content to 7.5 Gigahertz (GHz).

BACKGROUND OF THE INVENTION

The increase in digital data processor speeds has led to an increase in data transfer speeds. Transmission media used to connect electronic components to the digital data processors must be constructed to efficiently transmit the high speed digital signals between the various components. Wired media, such as fiber optic cable, coaxial cable, or twisted pair cable may be suitable in applications where the components being connected are in fixed locations and are relatively close proximity, e.g. separated by less than 100 meters. Fiber optic cable provides a transmission medium that can support data rates of up to nearly 100 Gb/s and is practically immune to electromagnetic interference. Coaxial cable typically supports data transfer rates up to 100 Megabits per second (Mb/s) and has good immunity to electromagnetic interference. Twisted pair cable can support data rates of up to about 5 Gb/s, although these cables typically require multiple twisted pairs within the cable dedicated to transmit or receive lines. The conductors of the twisted pair cables offer good resistance to electromagnetic interference which can be improved by including shielding for the twisted pairs within the cable.

Data transfer protocols such as Universal Serial Bus (USB) 3.0 and High Definition Multimedia Interface (HDMI) 1.4 require data transfer rates at or above 5 Gb/s. Existing coaxial cable cannot economically or reliably be implemented to support data rates near this speed. Both fiber optic and twisted pair cables are capable of transmitting data at these transfer rates, however fiber optic cables are significantly more expensive than twisted pair, making them less attractive for cost sensitive applications that do not require the high data transfer rates and electromagnetic interference immunity.

Infotainment systems and other electronic systems in automobiles and trucks are beginning to require cables capable of carrying high data rate signals. Automotive grade cables must not only be able to meet environmental requirements (e.g. thermal and moisture resistance), they must also be flexible enough to be routed in a vehicle wiring harness and have a low mass to help meet vehicle fuel economy requirements. Therefore, there is a need for a wire cable with a high data transfer rate that has low mass and is flexible enough to be packaged within a vehicle wiring harness, while meeting cost targets that cannot currently be met by fiber optic cable. Although the particular application given for this wire cable is automotive, such a wire cable would also likely find other applications, such as aerospace, maritime, industrial control, or other data communications.

The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may also be inventions.

BRIEF SUMMARY OF THE INVENTION

In accordance with one embodiment of this invention, an electrical connection system is provided. The electrical connection system includes a first shielded cable having a first electrical conductor and a second electrical conductor surrounded by a first shield conductor which is surrounded by a first insulating jacket, a second shielded cable having a third electrical conductor and a fourth electrical conductor surrounded by a second shield conductor which is surrounded by a second insulating jacket, a plug connector having a first plug terminal a second plug terminal, and a receptacle connector configured to mate with said plug connector having a first receptacle terminal and a second receptacle terminal configured to receive the first and second plug terminals respectively. The electrical connection system further includes a plug shield longitudinally surrounding the plug connector and electrically isolated from the plug terminals having an upper plug shield and a lower plug shield. The lower plug shield is attached to the first shield conductor by a first pair of shield crimp wings. An extremity of the first pair of shield crimp wings is collocated with an extremity of the first shield conductor. The electrical connection system additionally includes a receptacle shield longitudinally surrounding the receptacle connector and electrically isolated from the receptacle terminals having an upper receptacle shield and a lower receptacle shield. The lower receptacle shield is attached to the second shield conductor by a second pair of shield crimp wings. An extremity of the second pair of shield crimp wings is collocated with an extremity of the second shield conductor.

The extremity of the first pair of shield crimp wings may be in a range of 1.0 to 1.5 millimeters from the first and second attachment points and the extremity of the second pair of shield crimp wings may be in a range of 1.0 to 1.5 millimeters from the third and fourth attachment points.

The lower plug shield may be attached to the first insulating jacket by a first pair of jacket crimp wings and the lower plug shield may be attached to the upper plug shield by a first shield attaching feature located intermediate the first pair of shield crimp wings and the first pair of jacket crimp wings. The lower receptacle shield may be attached to the second insulating jacket by a second pair of jacket crimp wings and the lower receptacle shield may be attached to the upper receptacle shield by a second shield attaching feature located intermediate the second pair of shield crimp wings and the second pair of jacket crimp wings.

The upper plug shield may define a first tab in direct and compressive contact with the first pair of shield crimp wings of the lower plug shield and the upper receptacle shield may defines a second tab in direct and compressive contact with the second pair of shield crimp wings of the lower receptacle shield. Alternately or in addition, the upper plug shield may define a first pair of opposed tabs in direct and compressive contact with the first pair of shield crimp wings of the lower plug shield and the upper receptacle shield may define a second pair of opposed tabs in direct and compressive contact with the second pair of shield crimp wings of the lower receptacle shield.

The receptacle shield may be configured to slideably engage the interior of the plug shield. The extremity of the first pair of shield crimp wings may be substantially flush with the extremity of the first shield conductor and the extremity of the second pair of shield crimp wings may be substantially flush with the extremity of the second shield conductor

The first plug terminal may include a planar first connection portion that is characterized by a generally rectangular cross section and a first attachment portion attached to the first electrical conductor. The second plug terminal may also include a planar second connection portion that is characterized by a generally rectangular cross section and a second attachment portion attached to the second electrical conductor. The first and second plug terminals may form a first mirrored terminal pair having bilateral symmetry about a longitudinal axis. The first receptacle terminal may include a third attachment portion attached to the third electrical conductor and a first cantilever beam portion that is characterized by a generally rectangular cross section defining a convex first contact point depending from the first cantilever beam portion. The first contact point is configured to contact the first connection portion of the first plug terminal. The second receptacle terminal may include a fourth attachment portion attached to the fourth electrical conductor and have a second cantilever beam portion that is characterized by a generally rectangular cross section defining a convex second contact point depending from the second cantilever beam portion. The second contact point is configured to contact the second connection portion of the second plug terminal. The first and second receptacle terminals may form a second mirrored terminal pair having bilateral symmetry about the longitudinal axis. When the plug connector is connected to the receptacle connector, the major width of the first connection portion may be substantially perpendicular to the major width of the first cantilever beam portion and the major width of the second connection portion may be substantially perpendicular to the major width of the second cantilever beam portion.

Further features and advantages of the invention will appear more clearly on a reading of the following detailed description of the preferred embodiment of the invention, which is given by way of non-limiting example only and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The present invention will now be described, by way of example with reference to the accompanying drawings, in which:

FIG. **1** is a perspective cut away drawing of a shielded wire cable in accordance with one embodiment;

FIG. **2** is a cross section drawing of the wire cable of FIG. **1** in accordance with one embodiment;

FIG. **3** is a chart illustrating the signal rise time and desired cable impedance of several high speed digital transmission standards as measured from 10-90% of signal rise;

FIG. **4** is a chart illustrating various performance characteristics of the wire cable of FIGS. **1** and **2** in accordance with one embodiment;

FIG. **5** is a graph of the differential insertion loss versus signal frequency of the wire cables of FIGS. **1** and **2** in accordance with one embodiment;

FIG. **6** is an exploded perspective view of a wire cable assembly in accordance with one embodiment;

FIG. **7** is a perspective view of an electrical connector system of the wire cable assembly of FIG. **6** in accordance with one embodiment;

FIG. **8** is an exploded perspective view of the electrical connector system of FIG. **7** in accordance with one embodiment;

FIG. **9** is a top plan view of the electrical connector system of FIG. **7** in accordance with one embodiment;

FIG. **10**A is a cross section end view of a plug connector of the electrical connector system of FIG. **7** in accordance with one embodiment;

FIG. **10**B is a cross section end view of a receptacle connector of the electrical connector system of FIG. **7** in accordance with one embodiment; and

FIG. **11** is a cross section side view of the electrical connector system of FIG. **7** in accordance with one embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Presented herein is an electrical connector assembly for a shielded wire cable assembly that is capable of carrying digital signals at rates up to 5 Gigabits per second (Gb/s) (5 billion bits per second) to support both USB 3.0 and HDMI 1.4 performance specifications. The wire cable assembly includes a wire cable having a pair of conductors (wire pair) and a conductive sheet and braided conductor to isolate the wire pair from electromagnetic interference and determine the characteristic impedance of the cable. The wire pair is encased within dielectric belting that helps to provide a consistent radial distance between the wire pair and the shield. The belting may also help to maintain a consistent twist angle between the wire pair if they are twisted. The consistent radial distance between the wire pair and the shield and the consistent twist angle provides a wire cable with more consistent impedance. The wire cable assembly may also include an electrical receptacle connector having a mirrored pair of plug terminals connected to the wire pair and/or an electrical plug connector having a mirrored pair of receptacle terminals connected to the wire pair that is configured to mate with the plug terminals of the plug connector. The receptacle and plug terminals each have a generally rectangular cross section and when the first and second electrical connectors are mated, the major widths of the receptacle terminals are substantially perpendicular to the major widths of the plug terminals and the contact points between the receptacle and plug terminals are external to the receptacle and plug terminals. Both the receptacle and plug connectors include a shield that longitudinally surrounds the receptacle or plug terminals and is connected to the braided conductor of the wire cable. The wire cable assembly may also include an insulative connector body that contains the receptacle or plug terminals and shield.

FIGS. **1** and **2** illustrate a non-limiting example of a wire cable **100** used in the wire cable assembly. The wire cable **100** includes a central pair of conductors comprising a first inner conductor, hereinafter referred to as the first conductor **102** and a second inner conductor, hereinafter referred to as the second conductor **104**. The first and second conductors **102**, **104** are formed of a conductive material with superior conductivity, such as unplated copper or silver plated copper. As used herein, copper refers to elemental copper or a copper-based alloy. Further, as used herein, silver refers to elemental silver or a silver-based alloy. The design, construction, and sources of copper and silver plated copper conductors are well known to those skilled in the art. The first and second conductors **102**, **104** each comprise a solid wire conductor, such as a bare (non-plated) copper wire or silver plated copper wire having a diameter of about 0.321 millimeters (mm), which is generally equivalent to 28 AWG solid wire. Alternatively, the first and second conductors **102**, **104** may be formed of a solid wire having a smaller gauge, such as 30 AWG or 32 AWG. Alternative embodiments of the wire cable may use stranded wire for the first and second conductors **102**, **104**.

The central pair of first and second conductors **102**, **104** may be longitudinally twisted over a lay length L, for example once every 15.24 mm. Twisting the first and second conductors **102**, **104** provides the benefit of reducing low frequency electromagnetic interference of the signal carried by the central pair. However, the inventors have discovered that satisfactory signal transmission performance may also be provided by a wire cable wherein the first and second conductors **102**, **104** are not twisted about one about the other. Not twisting the first and second conductors **102**, **104** may provide the benefit of reducing manufacturing cost of the wire cable by eliminating the twisting process. Not twisting the first and second conductors **102**, **104** results in reduced differential insertion loss but has the disadvantage of requiring specific limitations in vehicle routing, specifically to non-uniform bending along the length of the cable run.

Each of the first and second conductors **102**, **104** are enclosed within a respective first dielectric insulator and a second dielectric insulator, hereafter referred to as the first and second insulators **108**, **110**. The first and second insulators **108**, **110** are bonded together. The first and second insulators **108**, **110** run the entire length of the wire cable **100**, except for portions that are removed at the extremities of the cable in order to terminate the wire cable **100**. The first and second insulators **108**, **110** are formed of a flexible dielectric material, such as polypropylene. The first and second insulators **108**, **110** may be characterized as having a thickness of about 0.85 mm.

Bonding the first insulator **108** to the second insulators **110** helps to maintain a consistent spacing S between the first and second conductors **102**, **104**. The methods required to manufacture a pair of conductors with bonded insulators are well known to those skilled in the art.

The first and second conductors **102**, **104** and the first and second insulators **108**, **110** are completely enclosed within a third dielectric insulator, hereafter referred to as the belting **112**, except for portions that are removed at the extremities of the cable in order to terminate the wire cable **100**. The first and second insulators **108**, **110** and the belting **112** together form a dielectric structure **113**.

The belting **112** is formed of a flexible dielectric material, such as polyethylene. As illustrated in FIG. **2**, the belting may be characterized as having a diameter D of 2.22 mm. A release agent **114**, such as a talc-based powder, may be applied to an outer surface of the bonded first and second insulators **108**, **110** in order to facilitate removal of the belting **112** from the first and second insulators **108**, **110** when ends of the first and second insulators **108**, **110** are stripped from the first and second conductors **102**, **104** to form terminations of the wire cable **100**.

The belting **112** is completely enclosed within a conductive sheet, hereafter referred to as the inner shield **116**, except for portions that may be removed at the extremities of the cable in order to terminate the wire cable **100**. The inner shield **116** is longitudinally wrapped in a single layer about the belting **112**, so that it forms a single seam **118** that runs generally parallel to the central pair of first and second conductors **102**, **104**. The inner shield **116** is not spirally wrapped or helically wrapped about the belting **112**. The seam edges of the inner shield **116** may overlap, so that the inner shield **116** covers at least 100 percent of an outer surface of the belting **112**. The inner shield **116** is formed of a flexible conductive material, such as aluminized biaxially oriented PET film. Biaxially oriented polyethylene terephthalate film is commonly known by the trade name MYLAR and the aluminized biaxially oriented PET film will hereafter be referred to as aluminized MYLAR film. The aluminized MYLAR film has a conductive aluminum coating applied to only one of the major surfaces; the other major surface is non-aluminized and therefore non-conductive. The design, construction, and sources for single-sided aluminized MYLAR films are well known to those skilled in the art. The non-aluminized surface of the inner shield **116** is in contact with an outer surface of the belting **112**. The inner shield **116** may be characterized as having a thickness of less than or equal to 0.04 mm.

The belting **112** provides the advantage of maintaining transmission line characteristics and providing a consistent radial distance between the first and second conductor **102**, **104** and the inner shield **116**. The belting **112** further provides an advantage of keeping the twist lay length between the first and second conductors **102**, **104** consistent. Shielded twisted pair cables found in the prior art typically only have air as a dielectric between the twisted pair and the shield. Both the distance between first and second conductors **102**, **104** and the inner shield **116** and the effective twist lay length of the first and second conductors **102**, **104** affect the wire cable impedance. Therefore a wire cable with more consistent radial distance between the first and second conductors **102**, **104** and the inner shield **116** provides more consistent impedance. A consistent twist lay length of the first and second conductors **102**, **104** also provides controlled impedance.

Alternatively, a wire cable may be envisioned incorporating a single dielectric structure encasing the first and second insulators to maintain a consistent lateral distance between the first and second insulators and a consistent radial distance between the first and second insulators and the inner shield. The dielectric structure may also keep the twist lay length of the first and second conductors consistent.

As shown in FIGS. **1** and **2**, the wire cable **100** additionally includes a ground conductor, hereafter referred to as the drain wire **120** that is disposed outside of the inner shield **116**. The drain wire **120** extends generally parallel to the first and second conductors **102**, **104** and is in intimate contact or at least in electrical communication with the aluminized outer surface of the inner shield **116**. The drain wire **120** comprises a solid wire conductor, such as an unplated copper conductor, tin plated copper conductor, or silver plated copper conductor having a cross section of about 0.321 mm^2, which is generally equivalent to 28 AWG solid wire. Alternatively, the drain wire **120** may be formed of solid wire having a smaller gauge, such as 30 AWG or 32 AWG. Alternative embodiments of the wire cable may use stranded wire for the drain wire **120**. The design, construction, and sources of copper and tin plated copper conductors are well known to those skilled in the art.

As illustrated in FIGS. **1** and **2**, the wire cable **100** further includes a braided wire conductor, hereafter referred to as the outer shield **124**, enclosing the inner shield **116** and the drain wire **120**, except for portions that may be removed at the ends of the cable in order to terminate the wire cable **100**. The outer shield **124** is formed of a plurality of woven conductors, such as copper or tin plated copper. As used herein, tin refers to elemental tin or a tin-based alloy. The design, construction, and sources of braided conductors used to provide such an outer shield are well known to those skilled in the art. The outer shield **124** is in intimate contact or at least in electrical communication with both the inner shield **116** and the drain wire **120**. The wires forming the outer shield **124** may be in contact with at least 65 percent of an outer surface of the inner shield **116**. The outer shield **124** may be characterized as having a thickness less than or equal to 0.30 mm.

The wire cable **100** shown in FIGS. **1** and **2** further includes an outer dielectric insulator, hereafter referred to as the jacket **126**. The jacket **126** encloses the outer shield **124**, except for portions that may be removed at the extremities of the cable in order to terminate the wire cable **100**. The jacket **126** forms an outer insulation layer that provides both electrical insulation and environmental protection for the wire cable **100**. The jacket **126** is formed of a flexible dielectric material, such as polyvinyl chloride (PVC). The jacket **126** may be characterized as having a thickness of about 0.2 mm.

The wire cable **100** is constructed so that the inner shield **116** is tight to the belting **112**, the outer shield **124** is tight to the drain wire **120** and the inner shield **116**, and the jacket **126** is tight to the outer shield **124** so that the formation of air gaps between these elements is minimized or compacted. This provides the wire cable **100** with controlled magnetic permeability.

The wire cable **100** may be characterized as having a differential impedance of 95 Ohms.

FIG. **3** illustrates the requirements for signal rise time (in picoseconds (ps)) and differential impedance (in Ohms (Ω)) for the USB 3.0 and HDMI 1.4 performance specifications. FIG. **3** also illustrates the combined requirements for a wire cable capable of simultaneously meeting both USB 3.0 and HDMI 1.4 standards. The wire cable is expected to meet the combined USB 3.0 and HDMI 1.4 signal rise time and differential impedance requirements shown in FIG. **7**.

FIG. **4** illustrates the differential impedances that are expected for the wire cables **100** over a signal frequency range of 0 to 7500 MHz (7.5 GHz).

FIG. **5** illustrates the insertion losses that are expected for wire cable **100** with a length of 7 m over the signal frequency range of 0 to 7500 MHz (7.5 GHz).

Therefore, as shown in FIGS. **4** and **5**, the wire cable **100** having a length of up to 7 meters are expected to be capable of transmitting non return to zero (NRZ) digital data at a speed of up to 5 Gigabits per second with an insertion loss of less than 20 dB.

As illustrated in the non-limiting example of FIG. **6**, the wire cable assembly includes an electrical connector assembly. The connector assembly includes a receptacle connector **128** and a plug connector **130** configured to accept the receptacle connector **128** as illustrated in FIG. **7**.

As illustrated in FIG. **8**, the receptacle connector **128** include two terminals, a first receptacle terminal **132** connected to a first inner conductor **102** and a second receptacle terminal **134** connected to a second inner conductor (not shown due to drawing perspective) of the wire cable **100**. The first receptacle terminal **132** includes a first cantilever beam portion **136** that has a generally rectangular cross section and defines a convex first contact point **138** that depends from the first cantilever beam portion **136** near the free end of the first cantilever beam portion **136**. The second receptacle terminal **134** also includes a similar second cantilever beam portion **140** having a generally rectangular cross section and defining a convex second contact point **142** depending from the second cantilever beam portion **140** near the free end of the second cantilever beam portion **140**. As best shown in FIG. **9**, the first and second receptacle terminals **132**, **134** each comprise an attachment portion **144** that is configured to receive the end of an inner conductor of the wire cable **100** and provide a surface for attaching the first and second inner conductors **102**, **104** to the first and second receptacle terminals **132**, **134**. The attachment portions **144** are configured to maintain the consistent spacing S between the first and second inner conductors **102**, **104**. In order to provide improved electromagnetic shielding, the outer shield **124** of the shielded cable **100** extends close to the attachment portion **144**. A receptacle terminal holder **148** partially encases the first and second receptacle terminal **132**, **134**. The receptacle terminal holder **148** maintains the spatial relationship between the first and second receptacle terminals **132**, **134** to maintain the consistent spacing S between the first and second inner conductors **102**, **104**. The first and second receptacle terminals **132**, **134** form a mirrored terminal pair that has bilateral symmetry about the longitudinal axis X and are substantially parallel to the longitudinal axis X and each other. In the illustrated embodiment, the distance between the first cantilever beam portion **136** and the second cantilever beam portion **140** is 2.85 mm, center to center. The first and second inner conductors **102**, **104** of the wire cable **100** are attached to the attachment portions **144** of the first and second receptacle terminals **132**, **134** using an ultrasonic welding process.

Referring once again to FIG. **8**, the plug connector **130** includes two terminals, a first plug terminal **160** connected to a first inner conductor **102** and a second plug terminal **162** connected to a second inner conductor **104** of the wire cable **100**. As best shown in FIG. **9**, the first plug terminal **160** includes a first elongate planar portion **164** that has a generally rectangular cross section. The second plug terminal **162** also includes a similar second elongate planar portion **166**. The planar portions of the plug terminals **160**, **162** are configured to receive and contact the first and second contact points **138**, **142** of the first and second receptacle terminals **132**, **134**. The free ends of the planar portions have a beveled shape to allow the mating first and second receptacle terminals **132**, **134** to ride up and over free ends of the first and second planar portions **164**, **166** when the plug connector **130** and receptacle connector **128** are mated. The first and second plug terminals **160**, **162** each comprise an attachment portion **144** similar to the attachment portions **144** of the first and second receptacle terminals **132**, **134** that are configured to receive the ends of the first and second inner conductors **102**, **104** and provide a surface for attaching the first and second inner conductors **102**, **104** to the first and second plug terminals **160**, **162**. The attachment portions **144** are configured to maintain the consistent spacing between the first and second inner conductors **102**, **104**. In order to provide improved electromagnetic shielding, the outer shield **124** of the shielded cable **100** extends close to the attachment portion **144**. A plug terminal holder **170** partially encases the first and second plug terminals **160**, **162**. The plug terminal holder **170** maintains the spatial relationship between the first and second plug terminals **160**, **162** to maintain the consistent spacing S between the first and second inner conductors **102**, **104**. The first and second plug terminals **160**, **162** form a mirrored terminal pair that has bilateral symmetry about the longitudinal axis X and are substantially parallel to the longitudinal axis X and each other. In the illustrated embodiment, the distance between the first planar portion and the second planar portion is 2.85 mm, center to center. The inventors have observed through data obtained from computer simulation that the mirrored parallel receptacle terminals **132**, **134** and plug terminals **160**, **162** have a strong effect on the high speed electrical properties, such as impedance and insertion loss, of the wire cable assembly. The first and second inner conductors **102**, **104** of the wire cable **100** are attached to the attachment portions **144** of the first and second plug terminals **160**, **162** using an ultrasonic welding process.

As illustrated in FIG. **8**, the first and second plug terminals **160**, **162** and the first and second receptacle terminals **132**, **134** are oriented in the plug and receptacle connectors **128**, **130** so that when the plug and receptacle connectors **128**, **130** are mated, the major widths of the first and second receptacle terminals **132**, **134** are substantially perpendicular to the major widths of the first and second plug terminals **160**, **162**. As used herein, substantially perpendicular means that the major widths are ±15° of absolutely perpendicular. The inventors have observed that this orientation between the first and second plug terminals **160**, **162** and the first and second receptacle terminals **132**, **134** has strong effect on insertion loss. Also, when the plug and receptacle connectors **128**, **130** are mated, the first and second receptacle terminals **132**, **134** overlap the first and second plug terminals **160**, **162**. The plug and receptacle connectors **128**, **130** are configured so that only the first and second contact points **138**, **142** of the first and second receptacle terminals **132**, **134** contacts the planar blade portion of the first and second plug terminals **160**, **162** and the contact area defined between the first and second receptacle terminals **132**, **134** and the first and second plug terminals **160**, **162** is less than the area overlapped between the first and second receptacle terminals **132**, **134** and the first and second plug terminals **160**, **162**. Therefore, the contact area, sometimes referred to as the wipe distance, is determined by the area of the first and second contact points **138**, **142** and not by the overlap between the terminals. Therefore, the receptacle terminals **132**, **134** and the plug terminals **160**, **162** provide the benefit of providing a consistent contact area as long as the first and second contact points **138**, **142** of the first and second receptacle terminals **132**, **134** are fully engaged with the first and second plug terminals **160**, **162**. Because both the plug and receptacle terminals are a mirrored pair, a first contact area between the first receptacle terminal **132** and the first plug terminal **160** and a second contact area between the second receptacle terminal **134** and the second plug terminal **162** are substantially equal. As used herein, substantially equal means that the contact area difference between the first contact area and the second contact area is less than 0.1 mm^2. The inventors have observed through data obtained from computer simulation that the contact area between the plug and receptacle terminals and the difference between the first contact are a and the second contact area have a strong impact on insertion loss of the wire cable assembly.

The first and second plug terminals **160**, **162** are not received within the first and second receptacle terminals **132**, **134**, therefore the first contact area is on the exterior of the first plug terminal **160** and the second contact area is on the exterior of the second plug terminal **162** when the plug connector **130** is mated to the receptacle connector **128**.

The first and second receptacle terminals **132**, **134** and the first and second plug terminals **160**, **162** may be formed from a sheet of copper-based material. The first and second cantilever beam portions **136**, **140** and the first and second planar portions **164**, **166** may be selectively plated using copper/nickel/silver based plating. The terminals may be plated to a 5 skin thickness. The first and second receptacle terminals **132**, **134** and the first and second plug terminals **160**, **162** are configured so that the receptacle connector **128** and plug connector **130** exhibit a low insertion normal force of about 0.4 Newton (45 grams). The low normal force provides the benefit of reducing abrasion of the plating during connection/disconnection cycles.

As illustrated in FIG. **8**, the plug connector **130** includes a plug shield **172** that is attached to the outer shield **124** of the wire cable **100**. The plug shield **172** is separated from and longitudinally surrounds the first and second plug terminals **160**, **162** and plug terminal holder **170**. The receptacle connector **128** also includes a receptacle shield **174** that is attached to the outer shield **124** of the wire cable **100** that is separated from and longitudinally surrounds the first and second receptacle terminals **132**, **134**, receptacle terminal holder **148** and receptacle terminal cover **152**. The receptacle shield **174** and the plug shield **172** are configured to slidingly contact one another and when mated, to provide electrical continuity between the outer shields **124** of the attached wire cables **100** and to provide electromagnetic shielding to the plug and receptacle connectors **128**, **130**.

As shown in FIG. **8**, the plug shield **172** is made of two parts, a lower plug shield **172**A and a upper plug shield **172**B. The lower plug shield **172**A includes two pairs of crimping wings: shield crimp wings **176** adjacent an attachment portion of the lower plug shield **172**A that is configured to receive the exposed end of the outer shield **124** of the wire cable **100** and jacket crimp wings **178**. The shield crimp wings **176** are bypass-type crimp wings that are offset and configured to surround the exposed end of the outer shield **124** of the wire cable **100** when the shield crimp wings **176** are crimped to the wire cable **110**. In order to reduce the effective electrical length of the plug shield **172**, an extreme end, i.e. extremity, of the shield crimp wings **176** is disposed on an extreme end, i.e. extremity, of the outer shield **124**. The extremity of the shield crimp wings **176** is within 1.0 to 1.5 mm of the attachment of the first and second conductors **102**, **104** to the attachment portions **144** of the plug terminals **160**, **162**. The drain wire **120** is electrically coupled to the lower plug shield **172**A when the lower plug shield **172**A is crimped to the outer shield **124** because the drain wire **120** of the wire cable **100** is sandwiched between the outer shield **124** and the inner shield **116** of the wire cable **110**.

The jacket crimp wings **178** are also bypass type wings that are offset and configured to surround the jacket **126** of the wire cable **100** when the lower plug shield **172**A is crimped to the wire cable **110**.

As illustrated in FIG. **10**A, the upper plug shield **172**B includes a pair of flexible tabs **146** located opposite one another that are positioned to directly contact the shield crimp wings **176** and apply a compressive force to the shield crimp wings **176**. These flexible tabs **146** provide improved electrical contact between the upper plug shield **172**B and the outer shield **124** than is provided when the upper plug shield **172**B is connected to the outer shield **124** only through the lower plug shield **172**A.

Referring again to FIG. **8**, the receptacle shield **174** is similarly made of two parts, a lower receptacle shield **174**A and a upper receptacle shield **174**B. The lower receptacle shield **174**A includes two pairs of crimping wings: shield crimp wings **176** adjacent an attachment portion of the lower receptacle shield **174**A that is configured to receive the exposed end of the outer shield **124** of the wire cable **100** and jacket crimp wings **178**. The shield crimp wings **176** are bypass-type crimp wings that are offset and configured to surround the exposed end of the outer shield **124** of the wire cable **100** when the shield crimp wings **176** are crimped to the wire cable **110**. In order to reduce the effective electrical length of the receptacle shield **174**, an extreme end, i.e. extremity, of the shield crimp wings **176** is disposed on an extreme end, i.e. extremity, of the outer shield **124**. The extremity of the shield crimp wings **176** is within 1.0 to 1.5 mm of the attachment of the first and second conductors **102**, **104** to the attachment portions **144** of the receptacle terminals **132**, **134**. The drain wire **120** is electrically coupled to the lower receptacle shield **174**A when the lower receptacle shield **174**A is crimped to the outer shield **124** because the drain wire **120** of the wire cable **100** is sandwiched between the outer shield **124** and the inner shield **116** of the wire cable **110**.

The insulation crimp wings are also bypass type wings that are offset and configured to surround the jacket **126** of the wire cable **100** when the lower receptacle shield **174**A is crimped to the wire cable **100**.

As illustrated in FIG. **10**B, the upper receptacle shield **174**B similarly includes a pair of flexible tabs **146** located opposite one another that are positioned to directly contact the shield crimp wings **176** and apply a compressive force to the shield crimp wings **176**. These flexible tabs **146** provide improved electrical contact between the upper receptacle shield **174**B and the outer shield **124** than is provided when the upper receptacle shield **174**B is connected to the outer shield **124** only through the lower receptacle shield **174**A.

While the exterior of the plug shield **172** of the illustrated example is configured to slideably engage the interior of the receptacle shield **174**, alternative embodiments may be envisioned wherein the exterior of the receptacle shield **174** slideably engages the interior of the plug shield **172**.

The receptacle shield **174** and the plug shield **172** may be formed from a sheet of copper-based material. The receptacle shield **174** and the plug shield **172** may be plated using copper/nickel/silver or tin based plating. The first and upper receptacle shield **174**A, **174**B and the first and upper plug shield **172**A, **172**B may be formed by stamping processes well known to those skilled in the art.

While the examples of the plug connector **130** and receptacle connector **128** illustrated herein are connected to a wire cable, other embodiments of the plug connector and receptacle connector may be envisioned that are connected to conductive traces on a circuit board.

To meet the requirements of application in an automotive environment, such as vibration and disconnect resistance, the wire cable assembly may further include a receptacle connector body **190** and a plug connector body **192** as illustrated in FIG. **6**. The receptacle connector body **190** and the plug connector body **192** are formed of a dielectric material, such as a polyester material.

Accordingly, a connector assembly is provided. The connector assembly is suited for terminating wire cables **100** and is capable of transmitting digital data signals with data rates of 3.5 Gb/s or higher without modulation or encoding. The connector assembly provides the benefit of improved electromagnetic shielding of the plug terminals **160**, **162** and receptacle terminals **132**, **134** due to the decreased effective lengths of the plug shield **172** and receptacle shield **174** provided by the location of the shield crimp wings **176** in close proximity to the attachment portions **144** of the terminals. The connector assembly also provides the benefit of improved electrical connections between the upper plug and receptacle shields **172**B, **174**B and the outer shields **124** of the wire cables **100**.

While this invention has been described in terms of the preferred embodiments thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Dimensions, types of materials, orientations of the various components, and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely prototypical embodiments.

Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the following claims, along with the full scope of equivalents to which such claims are entitled.

In the following claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, the use of the terms first, second, etc. does not denote any order of importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. Additionally, directional terms such as upper, lower, etc. do not denote any particular orientation, but rather the terms upper, lower, etc. are used to distinguish one element from another and locational establish a relationship between the various elements.

Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 USC § 112(f), unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

We claim:

1. An electrical connection system, comprising:

a first shielded cable having a first electrical conductor and a second electrical conductor surrounded by a first shield conductor which is surrounded by a first insulating jacket;

a second shielded cable having a third electrical conductor and a fourth electrical conductor surrounded by a second shield conductor which is surrounded by a second insulating jacket;

a plug connector having a first plug terminal and a second plug terminal;

a receptacle connector configured to mate with said plug connector having a first receptacle terminal and a second receptacle terminal configured to receive the first and second plug terminals respectively;

a plug shield longitudinally surrounding the plug connector and electrically isolated from the plug terminals having an upper plug shield and a lower plug shield, wherein the lower plug shield is attached to the first shield conductor by a first pair of shield crimp wings, wherein an extreme end of the first pair of shield crimp wings is collocated with an extreme end of the first shield conductor, wherein the upper plug shield defines a first tab in direct and compressive contact with an outer surface of the first pair of shield crimp wings of the lower plug shield, and wherein the first pair of shield crimp wings is intermediate the first tab and the first shield conductor; and

a receptacle shield longitudinally surrounding the receptacle connector and electrically isolated from the receptacle terminals having an upper receptacle shield and a lower receptacle shield, wherein the lower receptacle shield is attached to the second shield conductor by a second pair of shield crimp wings, wherein an extreme end of the second pair of shield crimp wings is collocated with an extreme end of the second shield conductor, wherein the upper receptacle shield defines a second tab in direct and compressive contact with an outer surface of the second pair of shield crimp wings of the lower receptacle shield, and wherein the second pair of shield crimp wings is intermediate the second tab and the second shield conductor;

wherein the upper plug shield defines a first pair of opposed tabs in direct and compressive contact with the first pair of shield crimp wings of the lower plug shield, wherein the first pair of shield crimp wings is intermediate the first pair of opposed tabs and the first shield conductor, wherein the upper receptacle shield defines a second pair of opposed tabs in direct and compressive contact with the second pair of shield crimp wings of the lower receptacle shield, and wherein the second pair of shield crimp wings is intermediate the second pair of opposed tabs and the second shield conductor.

2. The electrical connection system according to claim **1**, wherein the extreme end of the first pair of shield crimp wings is in a range of 1.0 to 1.5 millimeters from first and second attachment points and wherein the extreme end of the second pair of shield crimp wings is in a range of 1.0 to 1.5 millimeters from third and fourth attachment points.

3. The electrical connection system according to claim **1**, wherein the plug shield is configured to slideably engage the interior of the receptacle shield.

4. The electrical connection system according to claim **1**, wherein the extreme end of the first pair of shield crimp wings is substantially flush with the extreme end of the first shield conductor and wherein the extreme end of the second pair of shield crimp wings is substantially flush with the extreme end of the second shield conductor.

5. The electrical connection system according to claim **1**, wherein the first plug terminal includes a planar first connection portion characterized by a generally rectangular cross section and a first attachment portion attached to the first electrical conductor and wherein the second plug terminal includes a planar second connection portion characterized by a generally rectangular cross section and a second attachment portion attached to the second electrical conductor, wherein the first and second plug terminals form a first mirrored terminal pair having bilateral symmetry about a longitudinal axis; wherein the first receptacle terminal includes a third attachment portion attached to the third electrical conductor and a first cantilever beam portion characterized by a generally rectangular cross section defining a convex first contact point depending from the first cantilever beam portion, said first contact point configured to contact the first connection portion of the first plug terminal, wherein the second receptacle terminal includes a fourth attachment portion attached to the fourth electrical conductor and having a second cantilever beam portion characterized by a generally rectangular cross section defining a convex second contact point depending from the second cantilever beam portion, said second contact point configured to contact the second connection portion of the second plug terminal, wherein the first and second receptacle terminals form a second mirrored terminal pair having bilateral symmetry about the longitudinal axis and wherein when the plug connector is connected to the receptacle connector, the major width of the first connection portion is substantially perpendicular to the major width of the first cantilever beam portion and the major width of the second connection portion is substantially perpendicular to the major width of the second cantilever beam portion.

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